DOCUMENT RESUME

ED 135 582 SE 021 573

AUTHOR Zdravkovich, V.
TITLE Organic Chemistry Self Instructional Package 2: Methane.
INSTITUTION Prince George's Community Coll., Largo, Md.
PUB DATE 76
NOTE 58p.; For related Packages 1-17, see SE 021 572-588; Not available in hard copy due to copyright restrictions
AVAILABLE FROM Prince George's Community College Bookstore, Largo, Maryland 20870 ($17.00 a set, $1.00 ea.)

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS *Autoinstructional Aids; *Chemistry; *College Science; Higher Education; *Independent Study; Individualized Instruction; Individualized Programs; *Organic Chemistry; Science Education; Self Help Programs
IDENTIFIERS *Methane; Prince Georges Community College

ABSTRACT

This booklet, one of a series of 17 developed at Prince George's Community College, Largo, Maryland, provides an individualized, self-paced undergraduate organic chemistry instruction module designed to augment any course in organic chemistry but particularly those taught using the text "Organic Chemistry" by Morrison and Boyd. The entire series of modules covers the first 13 chapters of the Morrison-Boyd text in great detail. Each module has been provided with from one to three audiotapes, available from Prince George's Community College, to provide students additional explanations of particular concepts. Each module includes a self-evaluation exercise, a reference guide, worksheets to be completed with the audiotapes, answer sheets for the worksheets, a progress evaluation, an answer sheet for the progress evaluation, an answer sheet for the self-evaluation exercise, an introduction to the topic covered by the module, and student performance objectives for the module. The topic of this module is methane. (SL)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

ED135582

ORGANIC CHEMISTRY

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

V. Zdravkovich

2

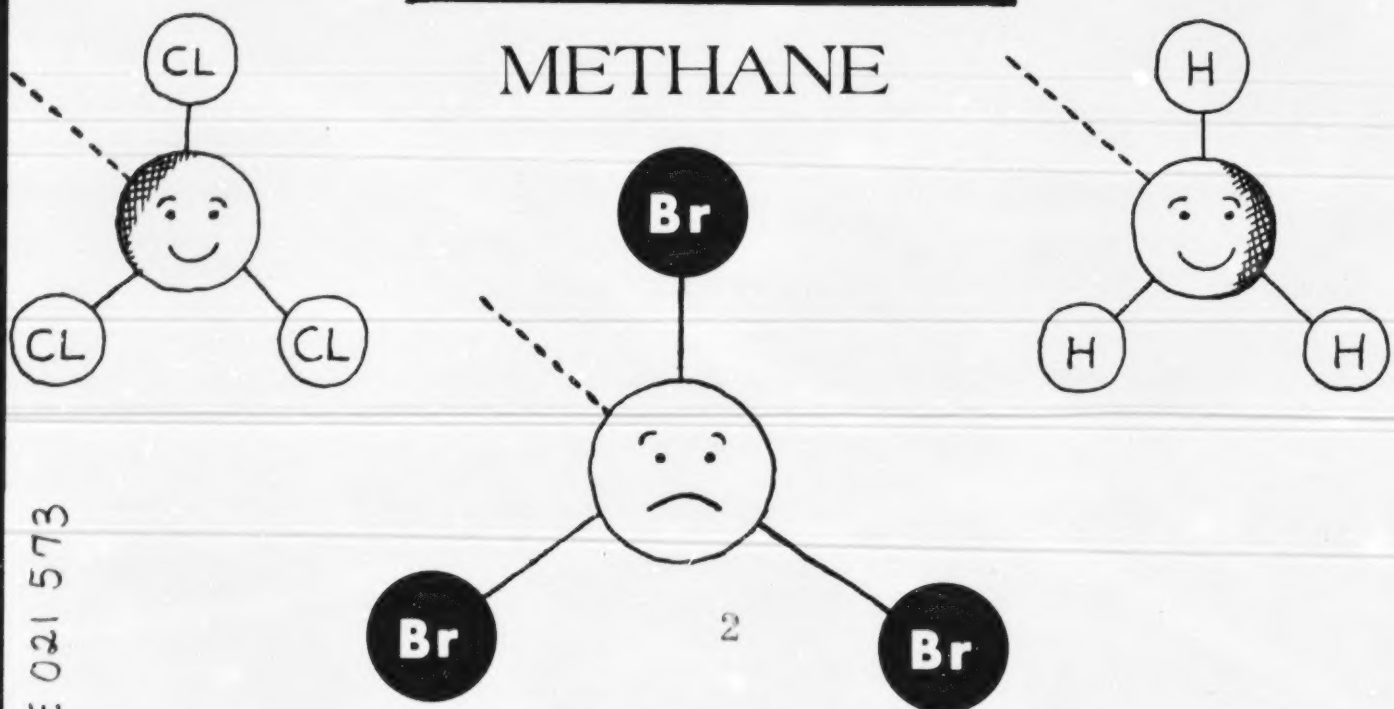
Self
Instructional
Package

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL BY MICROFICHE ONLY HAS BEEN GRANTED BY

V. Zdravkovich

TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE NATIONAL INSTITUTE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER

METHANE



SE 021 573

Self Instructional Sequence in

ORGANIC CHEMISTRY

"Copr.," V. Zdravkovich 1976

Self Instructional Package No. 2

METHANE

Introduction

The very first statement that a student crossing the threhold of the fascinating and endless field of organic chemistry learns is: carbon is tetrahedral, it forms four identical bonds directed toward the corners of a tetrahedron. Such a simple, unequivocal and well supported statement! Yet only a hundred years ago, prior to 1874, eminent scientists of that era firmly believed in a concept of two dimensions. Organic chemistry has grown from a concept of no dimensions prior to the nineteenth century through a concept of one dimension to the concept of two dimensions. In September and November of 1874 two papers appeared in the scientific world--one written by Jacobus van't Hoff, a Dutch chemist, and another by Jules LeBel, a French chemist. These two scientists working independently in different countries came up with a very similar concept - that of a tetrahedral carbon. This concept was not accepted at once. It was opposed and attacked by eminent chemists of the day. Kolbe, the first chemist to synthesize acetic acid and a well known scientist by then, greeted the theory with the following comments:

> "In a recently published paper I pointed out that one of the causes of the present day retrogression of chemical research in Germany is the lack of fundamental chemical knowledge. Under this lack no small number of our professors of chemistry are laboring, with great harm to the science. A consequence of this is the spread of the weed of the apparently scholarly and clever, but actually trivial and stupid natural philosophy, which was displaced fifty years ago by exact natural science, but which is now brought forth again out of the storeroom harboring the errors of the human mind by pseudo-scientists who try to smuggle it, like a fashionably dressed and freshly rouged prostitute, into good society where it does not belong. Anyone to whom this concern seems exaggerated may read the book by Messrs. van't Hoff and Herrmann on the Arrangement of Atoms in Space which has recently appeared and which overflows with fantastic foolishness...A Dr. J. H. van't Hoff of the Veterinary School at Utrecht has no liking, it seems, for exact chemical investigations. He has considered it more convenient to mount Pegasus (apparently borrowed from the Veterinary School) and to proclaim in his book how the atoms appear to him to be arranged in space when he is on the chemical Mt. Parnassus which he has reached by bold flight. It is indicative of the present day, in which critics are few and hated, that two practically unknown chemists, one from a veterinary school and the other from an agricultural institute, judge with such assurance the most important problems of chemistry, which may well never be solved--in particular, the question of the spatial arrangement of atoms--and undertake their answer with such courage as to astonish the real scientists."

Self Instructional Package No. 2
Form A

METHANE

Definitions

The student will be able to define or explain and illustrate with appropriate examples where applicable the following terms: HYDROCARBON, MONOHALOMETHANE, DIHALOMETHANE, TRIHALOMETHANE, TETRAHALOMETHANE, METHYL FREE RADICAL, SUBSTITUTION REACTION, COMBUSTION REACTION, HEAT OF COMBUSTION, HEAT OF REACTION, ACTIVATION ENERGY, TRANSITION STATE, Sp^2 HYBRIDIZATION, CHAIN INITIATING REACTION, CHAIN PROPAGATING STEPS, CHAIN TERMINATING STEPS.

Reactions

The student will be able to identify the reactants and the products in the combustion reaction of methane.

The student will be able to identify the reactants and the products in the halogenation reaction of methane, methylhalide, methylenehalide and haloform.

The student will be able to write the reactionfor the incomplete oxidation of methane.

Mechanism

The student will be able to write the step by step mechanism for the halogenation of methane reaction.

The student will be able to identify the chain initiating, the chain propagating and the chain terminating steps in the halogenation reaction mechanism.

The student will be able to identify the rate determining step in the halogenation reaction mechanism.

The student will be able to calculate the ΔH's for each step of the mechanism and for the overall reaction, utilizing the given bond energies.

The student will be able to draw the energy diagram for the halogenation reaction of methane identifying each step, individual ΔH's and the overall ΔH.

The student will be able to identify the activation energy and the different ΔH's on a given energy diagram.

The student will be able to write the structure for a transition state for different steps in the halogenation reaction mechanism.

The student will be able to describe the shape and explain the hybridization on the carbon atom in the methyl free radical.

Self Instructional Package No. 2
Form B - Self Evaluation Exercise

METHANE

You will fill out this exercise by blacking in the appropriate squares on an answer sheet. There may be more than one correct answer for each question.

1. In the following grcup of compounds identify hydrocarbons.

   a) SiH_4

   b) C_6H_6

   c) CO_2

   d) C_8H_{18}

2. The shape of methane is:

   a) pyramidal

   b) flat - square

   c) trigonal planar

   d) tetrahedral

3. The bond angle in methane is:

   a) 120°

   b) 90°

   c) 180°

   d) 109°

4. The low boiling temperature of methane is due to:

   a) the strong intermolecular forces between methane molecules

   b) the weak van der waals forces between methane molecules

   c) the fact that bonds within methane molecules are nonpolar

   d) the fact that the methane molecule is nonpolar

5. The following reaction of methane represents a typical:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \Delta H$$

a) oxidation reaction

b) combustion reaction

c) substitution reaction

d) free radical reaction

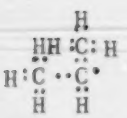
6. Identify monohalomethane in the group of compounds given below:

a) CH_2Br_2

b) CF_4

c) CH_3I

d) $CHCl_3$

7. The following species  is a typical:

a) positive ion

b) free radical

c) species with a tendency to give up one electron

d) species with a tendency to gain one electron

8. The rate determining step in the halogenation of methane consists of:

a) homolytic cleavage of the halogen molecule

b) abstraction of a halogen atom by a methyl radical

c) reaction of methane with a halogen atom

d) formation of a methyl free radical and hydrogen halide

9. Halogenation of methane can be terminated via:

   a) reaction of two halogen atoms to form a halogen molecule

   b) reaction of a halogen molecule with a methyl free radical to form a methyl halide and a halogen atom

   c) reaction of a methyl free radical and a halogen atom to form a methyl halide

   d) reaction of two methyl free radicals to form an ethane molecule

10. Correct definitions and properties of activation energy are:

   a) It is the minimum amount of energy thatmust be provided by a collision for reaction to occur.

   b) It is the difference in energy content between reactants and the transition state.

   c) It is high for exothermic reactions.

   d) It is at least as high as ΔH for endothermic reactions.

11. One factor which does not affect the rate of a chemical evaluation is the:

   a) heat released in the reaction

   b) energy of activation

   c) number of collisions per unit volume and unit time

   d) probability thatthe reactants will be properly oriented

12. The explanation for the observed reactivity sequence in the halogenation of methane (Fluorine - most reactive: Iodine - least reactive) is:

   a) the low dissociation energy of fluorine

   b) the highly exothermic abstraction of the fluorine atom by the methyl radical

   c) the difference in activation energies for the abstraction of a halogen atom by a methyl radical expressed in kcal/mole:

   ΔH (F) =-71 ΔH = -23 ΔH (Br) = -21 ΔH (I) = -17

   d) difference in activation energies for the abstraction of a hydrogen atom and formation of a methyl free radical

13. The following step or steps represent the chain terminating step in the halogenation of methane.

a) $CH_3^\bullet + CH_3^\bullet \longrightarrow CH_3 - CH_3$

b) $CH_3^\bullet + X_2 \longrightarrow CH_3X + X^\bullet$

c) $X^\bullet + {}^\bullet X \longrightarrow X_2$

d) $CH_3^\bullet + {}^\bullet X \longrightarrow CH_3 - X$

14. The following step or steps represent the chain propagating step in the halogenation of methane.

a) $CH_3^\bullet + X_2 \longrightarrow CH_3X + X^\bullet$

b) $CH_4 + X^\bullet \longrightarrow CH_3^\bullet + HX$

c) $CH_3^\bullet + X^\bullet \longrightarrow CH_3 - X$

d) $CH_3^\bullet + CH_3^\bullet \longrightarrow CH_3 - CH_3$

15. The rate determining step in the free radical halogenation of methane is:

a) $CH_3 + X_2 \longrightarrow CH_3X + X^\bullet$

b) $CH_4 + X^\circ \longrightarrow CH_3^\bullet + HX$

c) $CH_3 + CH_3^\bullet \longrightarrow CH_3 - CH_3$

d) $X_2 + \text{heat} \longrightarrow 2X^\bullet$

16. Using the values given on the bond energy card you can calculate the ΔH for the monobromination of methane. This value is:

a) -25 kcal/mole

b) -8 kcal/mole

c) +16 kcal/mole

d) -24 kcal/mole

9

17. Using the same bond energy card one can calculate the ΔH for the rate determining step or the abstraction of a hydrogen atom from a methane molecule by the chlorine atom. This value is:

a) +58 kcal/mole

b) +1 kcal/mole

c) -26 kcal/mole

d) -25 kcal/mole

18. The following statements about an endothermic reaction are correct:

a) It is a reaction in which energy is released.

b) It is a reaction for which energy is required.

c) In an endothermic reaction, the products possess lower amounts of potential energy or "they have a lower potential energy valley" than the reactants.

d) In an endothermic reaction products possess a higher amount of potential energy or "they have a higher potential energy valley" than the products.

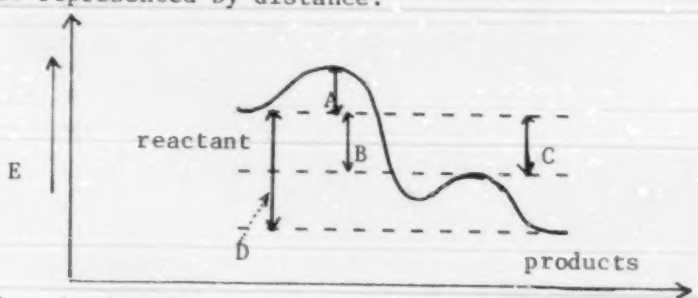
19. In the energy diagram for the chlorination reaction given below the heat of reaction ΔH is represented by distance:

a) A

b) B

c) C

d) D



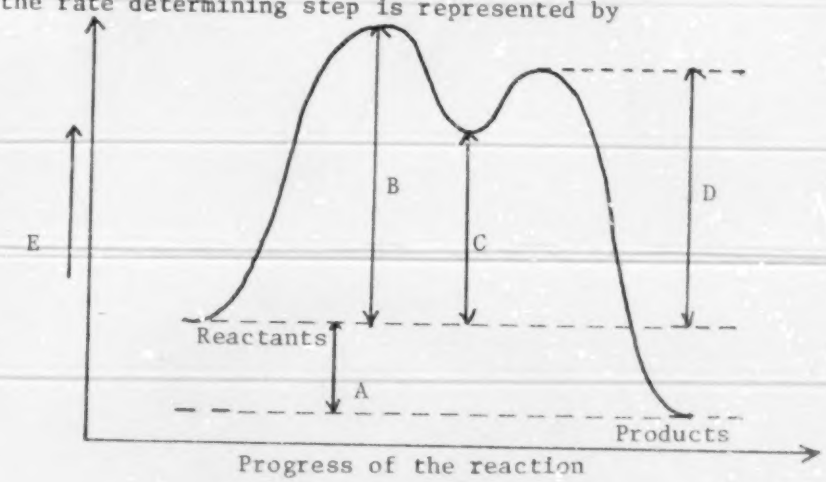
20. In the energy diagram for the bromination reaction given below the activation energy for the rate determining step is represented by distance:

a) A

b) B

c) C

d) D



21. Inhibitors are:

a) compounds which speed up a chemical reaction.

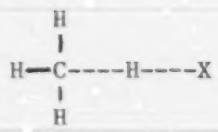
b) compounds which slow down a chemical reaction.

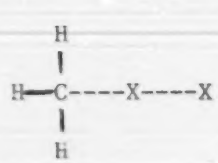
c) an example of inhibitors is halogen in the halogenation of methane reaction.

d) an example of inhibitors is oxygen in the halogenation of methane reaction.

22. Identify one of the species below as the transition state for the rate determining step or the abstraction of the hydrogen atom from methane by the halogen atom.

a) $CH_3^{\bullet}$

b)


c)


d) X----X

23. The shape of the methyl free radical $CH_3^{\bullet}$ is:

a) flat trigonal

b) pyramidal

c) tetrahedral

d) square

Self Instructional Package No. 2
Form C - Reference Guide

METHANE

The reference guide should be used in conjunction with Form B or the Self Evaluation Exercise. The references given are geared specifically toward the questions on Form B.

Question 1	Chapter 2	Section 1
Questions 2, 3	Chapter 2	Section 2, S.I.P. No. 1 - Tape 1
Question 4	Chapter 2	Section 3
Question 5	Chapter 2	Section 6
Question 6	Chapter 2	Sections 7, 9
Question 7	Chapter 2	Section 12
Questions 9, 13, 14,	Chapter 2	Section 13
Questions 16, 17, 18	Chapter 2	Sections 15, 17
Questions 8, 10	Chapter 2	Section 16
Questions 19, 20	Chapter 2	Section 17
Question 12	Chapter 2	Section 20
Question 11	Chapter 2	Sections 18, 19
Question 8	Chapter 2	Section 20
Question 21	Chapter 2	Section 14
Question 22	Chapter 2	Sections 22, 23
Question 23	Chapter 2	Section 21

Morrison and Boyd Organic Chemistry

For Questions 2 and 3, additional explanation can be found in the S.I.P No. 1 - Tape 1 - sp^3 Hybridization on the Carbon Atom.

For Questions 6, 7, 9, 13, 14, 15 additional explanation and examples can be found in Tape 1 - Methane - Halogenation Reaction.

For Questions 16, 17, 18 additional explanation and examples can be found in Tape 2 - Methane - Energy Aspect of the Halogenation Reaction.

For Questions 8, 10, 12, 19, 20, 22 additional explanation and examples can be found in Tape 3 - Energy Diagram for the Halogenation Reaction.

Self Instructional Package 2
Tape 1 - Worksheet

OBJECTIVES:
1. To learn the halogenation reaction of methane.
2. To learn the mechanism of the halogenation reaction of methane.
3. To learn the concept of free radicals.

Example 1. Monohalogenation of Methane

$$CH_4 + X_2 \xrightarrow{\text{heat or light}} CH_3X + HX$$

methane halogen monohalo-methane methylhalide

Example 2. Monofluorination of Methane

$$CH_4 + F_2 \xrightarrow{\text{heat or light}} CH_3F + HF$$

(Heat is conventionally depicted by a small triangle followed by a capital H. Light is conventionally depicted by the letters hν.)

ASSIGNMENT 1. Write the overall reactions for:

a) Monochlorination of methane:

b) Monobromination of methane :

c) Monoiodination of methane :

Example 3. Mono, di, tri, and tetrahalogenation of methane

methane → monohalomethane (methyl halide) → dihalomethane (methylene halide) → →

$$CH_4 \xrightarrow[\Delta H \text{ or } h\nu]{X_2} CH_3X + HX \xrightarrow[\Delta H \text{ or } h\nu]{X_2} CH_2X_2 + HX \xrightarrow[\Delta H \text{ or } h\nu]{X_2}$$

trihalomethane (haloform) → tetrahalomethane (carbon tetrahalide)

$$CHX_3 + HX \xrightarrow[\Delta H \text{ or } h\nu]{X_2} CX_4 + HX$$

ASSIGNMENT 2. Fill in the blanks for the bromination of methane reaction.

$$CH_4 \xrightarrow[\Delta H \text{ or } h\nu]{Br_2} \underline{\quad\quad} + \underline{\quad\quad} \xrightarrow[\Delta H \text{ or } h\nu]{Br_2} CH_2Br_2 + \underline{\quad\quad} \xrightarrow[\Delta H \text{ or } h\nu]{Br_2}$$

Names: _____ _____

$$\underline{\quad\quad} + HX \xrightarrow[H \text{ or } h\nu]{Br_2} \underline{\quad\quad} + \underline{\quad\quad}$$

Names: _____ _____

ASSIGNMENT 3. Write all the possible products for the following reactions:

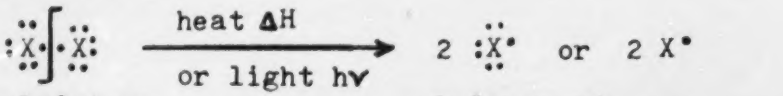
a) Fluorination of methane:

b) Chlorination of methane:

c) Iodination of methane :

Example 4. Step-by-step mechanism for the free radical halogenation of methane.

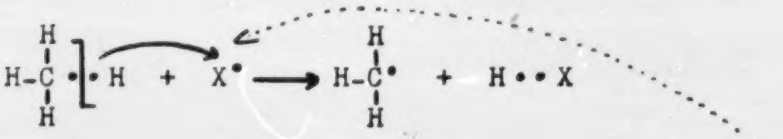
I Step 1. Homolytic cleavage - CHAIN INITIATING STEP:



halogen molecule — halogen atom or halogen free radical

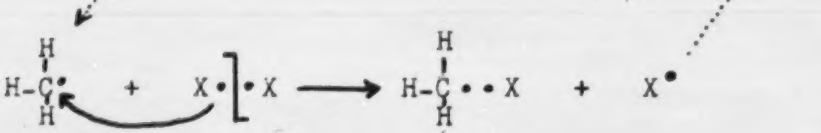
II CHAIN PROPAGATING STEPS:

Step 2.



methane — halogen atom — methyl free radical — hydrogen halide

Step 3.



methyl free radical — halogen molecule — methyl halide — halogen free radical

15

III CHAIN TERMINATING STEPS:

a) $X^{\bullet} + X^{\bullet} \longrightarrow X_2$

b) $CH_3^{\bullet} + X^{\bullet} \longrightarrow CH_3X$

c) $CH_3^{\bullet} + CH_3^{\bullet} \longrightarrow C_2H_6$

ASSIGNMENT 4. Write the step-by-step mechanism for the monobromination of methane.

ASSIGNMENT 5-a Step-by-step mechanism for the monochlorination of methane.

CHAIN INITIATING STEP:

Step 1. $Cl_2 \longrightarrow 2Cl^{\bullet}$

CHAIN PROPAGATING STEPS:

Step 2. $CH_4 + Cl^{\bullet} \longrightarrow CH_3Cl + H^{\bullet}$

Step 3. $H^{\bullet} + Cl_2 \longrightarrow HCl + Cl^{\bullet}$

CHAIN TERMINATING STEPS:

$Cl^{\bullet} + Cl^{\bullet} \longrightarrow Cl_2$

$H^{\bullet} + H^{\bullet} \longrightarrow H_2$

$H^{\bullet} + Cl^{\bullet} \longrightarrow HCl$

ASSIGNMENT 5-b Step-by-step mechanism for the monobromination of methane.

Step 1. $Br_2 \xrightarrow{h\nu \text{ or } \Delta} 2Br^{\bullet}$ Chain initiating step

Step 2. $Br^{\bullet} + CH_4 \longrightarrow CH_3Br + HBr$

Chain propagating steps

Step 3. $CH_3^{\bullet} + 2Br^{\bullet} \longrightarrow CH_3Br + Br^{\bullet}$

$Br^{\bullet} + Br^{\bullet} \longrightarrow Br_2$

$CH_3^{\bullet} + Br^{\bullet} \longrightarrow CH_3Br$

Chain terminating steps

ASSIGNMENT 6. Definition for homolytic cleavage:

Examples of a typical homolytic cleavage:

Self Instructional Package No. 2
Tape 1 - Answer Sheet

METHANE

HALOGENATION REACTION

Assignment No. 1

a) Monochlorination of methane:

$$CH_4 + Cl_2 \xrightarrow{\Delta H \text{ or } hv} CH_3Cl + HCl$$

monochloromethane or
methyl chloride

b) Monobromination of methane:

$$CH_4 + Br_2 \xrightarrow{\Delta H \text{ or } hv} CH_3Br + HBr$$

monobromethane or
methyl bromide

c) Monoiodination of methane:

$$CH_4 + I_2 \xrightarrow{\Delta H \text{ or } hv} CH_3I + HI$$

monoiodomethane or
methyl iodide

Assignment No. 2

$$CH_4 \xrightarrow[\Delta H \text{ or } hv]{Br_2} CH_3Br + HBr \xrightarrow[\Delta H \text{ or } hv]{Br_2} CH_2Br_2 + HBr \xrightarrow[\Delta H \text{ or } hv]{Br_2} CHBr_3 + HBr \xrightarrow[\Delta H \text{ or } hv]{Br_2} CBr_4 + HBr$$

Names: monobromomethane or methyl bromide

dibromomethane or methylene bromide

tribromomethane or bromoform

tetrabromomethane or carbontetrabromide

SIP No. 2
Tape 1 - Answer Sheet

Assignment No. 3

a) Fluorination of methane:

$$CH_4 \xrightarrow[\Delta H \text{ or } h\nu]{F_2} CH_3F + HF \xrightarrow[\Delta H \text{ or } h\nu]{F_2} CH_2F_2 + HF \xrightarrow[\Delta H \text{ or } h\nu]{F_2} CHF_3 + HF \xrightarrow[\Delta H \text{ or } h\nu]{F_2} CF_4 + HF$$

monofluoromethane or methyl fluoride

difluoromethane or methylene fluoride

trifluoromethane or fluoroform

tetrafluoromethane or carbonetetra fluoride

b) Chlorination of methane:

$$CH_4 \xrightarrow[\Delta H \text{ or } h\nu]{Cl_2} CH_3Cl + HCl \xrightarrow[\Delta H \text{ or } h\nu]{Cl_2} CH_2Cl_2 + HCl \xrightarrow[\Delta H \text{ or } h\nu]{Cl_2} CHCl_3 + HCl \xrightarrow[\Delta H \text{ or } h\nu]{Cl_2} CCl_4 + HCl$$

monochloromethane or methyl chloride

dichloromethane or methylene chloride

trichloromethane or chloroform

tetrachloro methane or carbontetra chloride

c) Iodination of methane:

$$CH_4 \xrightarrow[\Delta H \text{ or } h\nu]{I_2} CH_3I + HI \xrightarrow[\Delta H \text{ or } h\nu]{I_2} CH_2I_2 + HI \xrightarrow[\Delta H \text{ or } h\nu]{I_2} CHI_3 + HI \xrightarrow[\Delta H \text{ or } h\nu]{I_2} CI_4 + HI$$

monoiodomethane or methyl iodide

diiodomethane or methylene iodide

triiodomethane or iodoform

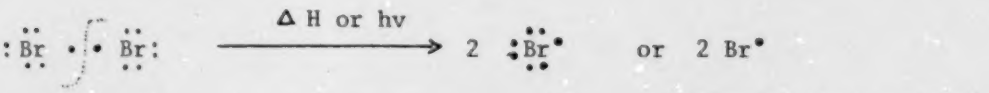
tetraiodomethane or carbontetraiodide

SIP No. 2
Tape 1 - Answer Sheet

Assignment No. 4

Step-by-step mechanism for the monobromination of methane

I - Chain initiating step



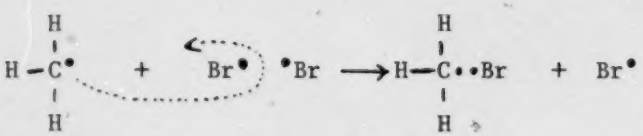
bromine free radical

II - Chain propagating steps

Step 2:

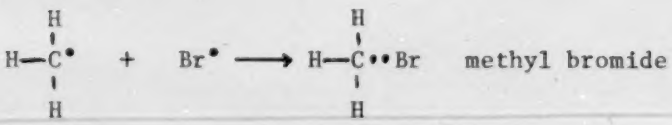
methyl free radical

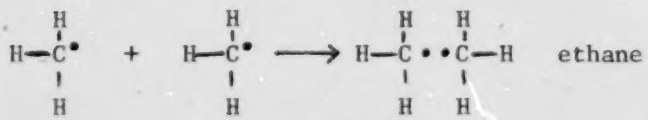
Step 3:



methyl bromide

III. Chain terminating steps





SIP No. 2
Tape 1 - Answer Sheet

Assignment No. 5

a) Step by step mechanism for the monochlorination of methane

Chain initiating step:

Step 1:

$$Cl_2 \xrightarrow{\Delta \text{ or } h\nu} 2Cl^{\bullet} \qquad \text{(correct)}$$

Chain propagating steps:

Step 2:

$$CH_4 + Cl^{\bullet} \longrightarrow CH_3Cl + H^{\bullet} \qquad \text{(incorrect)}$$

$$CH_4 + Cl^{\bullet} \longrightarrow CH_3^{\bullet} + HCl \qquad \text{(correct)}$$

Step 3:

$$H^{\bullet} + Cl_2 \longrightarrow HCl + Cl^{\bullet} \qquad \text{(incorrect)}$$

$$CH_3^{\bullet} + Cl_2 \longrightarrow CH_3Cl + Cl^{\bullet} \qquad \text{(correct)}$$

Chain terminating steps:

$$Cl^{\bullet} + Cl^{\bullet} \longrightarrow Cl_2 \qquad \text{(correct)}$$

$$H^{\bullet} + H^{\bullet} \longrightarrow H_2 \qquad \text{(incorrect)}$$

$$CH_3^{\bullet} + CH_3^{\bullet} \longrightarrow CH_3 - CH_3 \qquad \text{(correct)}$$

$$H^{\bullet} + Cl^{\bullet} \longrightarrow HCl \qquad \text{(correct)}$$

b) Step-by-step mechanism for the monobromination of methane

Chain initiating step:

Step 1:

$$Br_2 \xrightarrow{h\nu \text{ or } \Delta} 2\ Br^{\circ}$$

Chain propagating steps:

Step 2:

$$Br^{\bullet} + CH_4 \longrightarrow CH_3Br + HBr \qquad \text{(incorrect)}$$

$$Br^{\bullet} + CH_4 \longrightarrow CH_3^{\bullet} + HBr \qquad \text{(correct)}$$

Step 3:

$$CH_3^{\bullet} + 2Br^{\bullet} \longrightarrow CH_3Br + Br^{\bullet} \qquad \text{(incorrect)}$$

$$CH_3^{\bullet} + Br_2 \longrightarrow CH_3Br + Br^{\bullet} \qquad \text{(correct)}$$

Assignment No. 5 (continued)

Chain terminating steps:

$Br^{\bullet} + Br^{\bullet} \longrightarrow Br_2$ (correct)

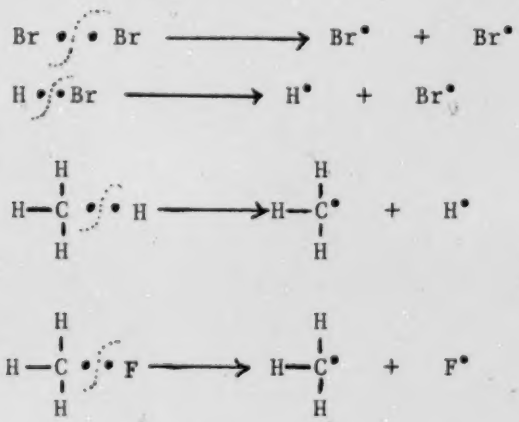
$CH_3^{\bullet} + Br^{\bullet} \longrightarrow CH_3Br$ (correct)

$CH_3^{\bullet} + CH_3^{\bullet} \longrightarrow CH_3 - CH_3$

Assignment No. 6

Homolytic cleavage or homolysis is the bond dissociation in which the two electrons making up the covalent bond break in such a manner that one electron goes to each fragment. Homo in Greek means the same; lysis means a loosing.

Examples of a typical homolytic cleavage:

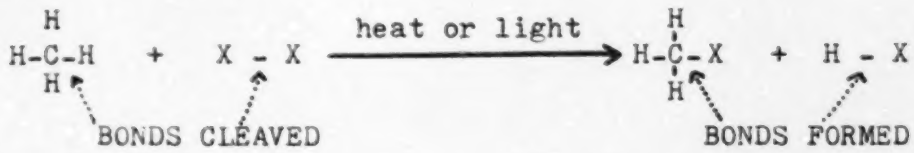


Self Instructional Package 2
Tape 2 - Worksheet

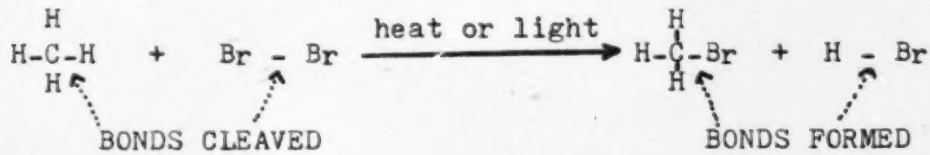
OBJECTIVES:

1. To learn how to calculate the energy or ΔH for the overall halogenation reaction.
2. To learn how to calculate the energy or ΔH for each step of the mechanism.
3. To learn how to calculate the energy or ΔH for the overall reaction from the energies calculated for the individual steps of the mechanism.

Example 1. Halogenation of methane



Example 2. Bromination of methane



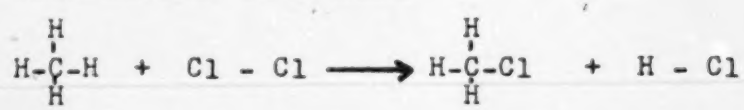
104 $\frac{kcal}{mole}$ + 46 $\frac{kcal}{mole}$ — 150 $\frac{kcal}{mole}$ (E required)

70 $\frac{kcal}{mole}$ + 88 $\frac{kcal}{mole}$ — 158 $\frac{kcal}{mole}$ (E released)

a) $\Delta H = -8 \frac{kcal}{mole}$ (E is released in the overall reaction.)

b) $CH_4 + Br_2 \xrightarrow{\text{heat or light}} CH_3Br + HBr + 8 \frac{kcal}{mole}$

ASSIGNMENT 1. Chlorination of methane



a) Bond energies: _____ C - H; _____ Cl - Cl; _____ C - Cl; _____ H - Cl

Bonds cleaved:

Bonds formed:

E required:

E released:

ASSIGNMENT 1. cont.

b) ΔH for the chlorination reaction.

c) Chlorination of methane is an ENDOTHERMIC, EXOTHERMIC (circle one) reaction.

d)

ASSIGNMENT 2. ΔH = 102 for the fluorination of methane reaction.

a) Write the reaction:

b) The value for ΔH given above is correct, incorrect (circle one).
If the answer in part a) is incorrect, the correct value is: ΔH= _____

c)

ASSIGNMENT 3. Esterification reaction.

Bond energies: _____ _____ _____ _____

a) ΔH =

b) Reaction above is ENDOTHERMIC, EXOTHERMIC (circle one).

c) Reaction WILL, WILL NOT (circle one) take place spontaneously.

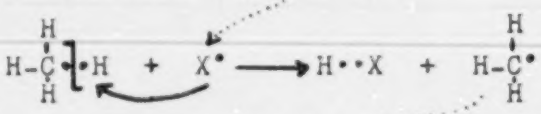
Example 3. Mechanism of the halogenation of methane.

I CHAIN INITIATING STEP:

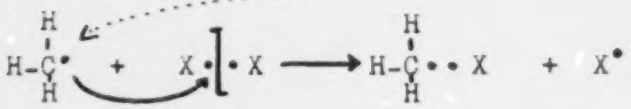
Step 1. $X\!:\!X \xrightarrow{\Delta H \text{ or } h\nu} 2\,X^{\bullet}$

II CHAIN PROPAGATING STEPS:

Step 2.

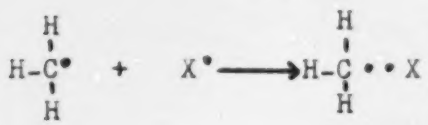


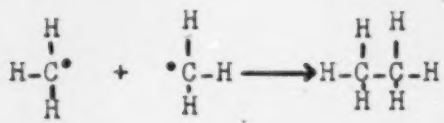
Step 3.



III CHAIN TERMINATING STEPS:

$X^{\bullet} + X^{\bullet} \longrightarrow X\!:\!X$ or X_2





Example 4. Mechanism

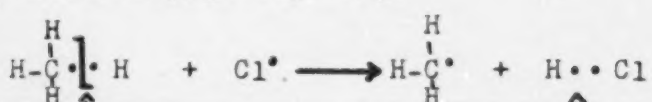
I Chain Initiating Step

Step 1. $Cl\!:\!Cl \longrightarrow 2Cl^{\bullet}$ $\Delta H = +58 \frac{\text{kcal}}{\text{mole}}$

58 $\frac{\text{kcal}}{\text{mole}}$ (required) E is required for Step 1.

II Chain Propagating Steps

Step 2.

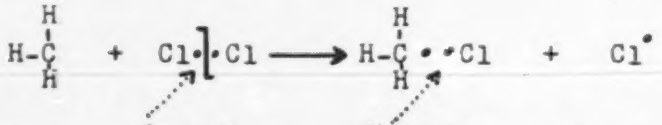


104 $\frac{\text{kcal}}{\text{mole}}$ (required) 103 $\frac{\text{kcal}}{\text{mole}}$ (released)

$\Delta H = +104 - 103 = +1 \frac{\text{kcal}}{\text{mole}}$ E is required for Step 2.

Example 4. cont.

Step 3.



58 kcal/mole (required) 84 kcal/mole (released)

$\Delta H = +58 - 84 = -26$ kcal/mole E is released in Step 3.

ASSIGNMENT 4. Monobromination of methane

I Chain initiating step

Step 1.

$\Delta H =$ _____

Step 1. is ENDOTHERMIC
EXOTHERMIC

II Chain propagating steps

Step 2.

$\Delta H =$ _____

Step 2. is ENDOTHERMIC
EXOTHERMIC

Step 3.

$\Delta H =$ _____

Step 3. is ENDOTHERMIC
EXOTHERMIC

ASSIGNMENT 5. Monoiodination of methane

$\Delta H_1 = +56$ kcal/mole
$\Delta H_2 = -36$ kcal/mole
$\Delta H_3 = +20$ kcal/mole
$\Delta H_4 = +33$ kcal/mole

ASSIGNMENT 5. cont.

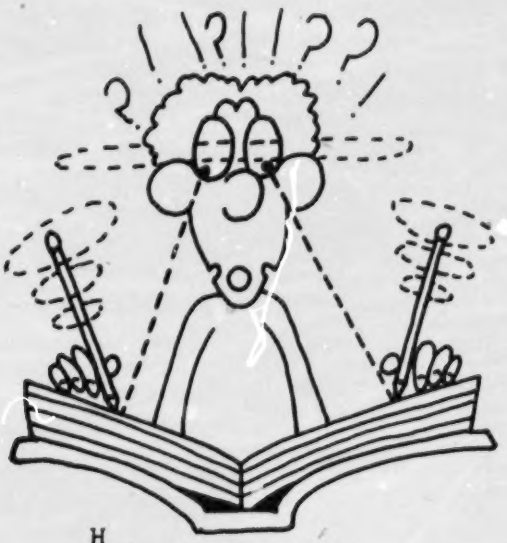
ΔH_1 corresponds to step ____. It should be properly written with a + or a - sign _____.

ΔH_2 corresponds to step ____. It should be properly written with a + or a - sign _____.

ΔH_3 corresponds to step ____. It should be properly written with a + or a - sign _____.

ΔH_4 corresponds to step ____. It should be properly written with a + or a - sign ____.

Example 5. Halogenation of methane



I Chain initiating step

Step 1. $X{\bullet\bullet}X \xrightarrow{\Delta \text{ or } h\nu} 2X^{\bullet}$

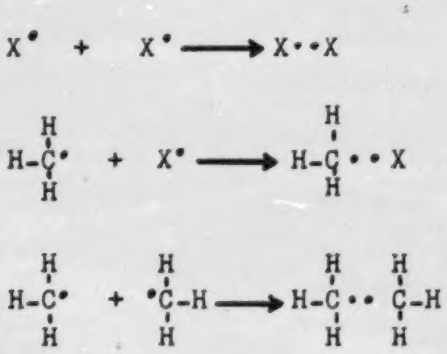
II Chain propagating steps

Step 2. $H\text{-}\underset{H}{\overset{H}{C}}\bullet\!\!\bullet H + X^{\bullet} \longrightarrow H{\bullet\bullet}X + H\text{-}\underset{H}{\overset{H}{C}}\bullet$

Step 3. $H\text{-}\underset{H}{\overset{H}{C}}\bullet + X\bullet\!\!\bullet X \longrightarrow H\text{-}\underset{H}{\overset{H}{C}}{\bullet\bullet}X + X^{\bullet}$

Example 5. cont.

III Chain terminating steps



The combination of the two chain propagating steps:

_____ ⟶ _____

Combined left sides of steps 2 a d 3.

Combined right sides of steps 2 and 3.

ASSIGNMENT 6. Monobromination reaction of methane

Utilizing the ΔH's for the individual steps of the reaction mechanism as calculated in ASSIGNMENT 4, the ΔH for the overall reaction is: ΔH = _____.
SHOW WORK!

Monoiodination reaction of methane

Utilizing the ΔH's for the individual steps of the reaction mechanism as calculated in ASSIGNMENT 5, the ΔH for the overall reaction is: ΔH = _____.
SHOW WORK!

ASSIGNMENT 7.

Fluorination of methane

Answer provided by Forgetful Flora is:

ΔH = 64 kcal/mole.

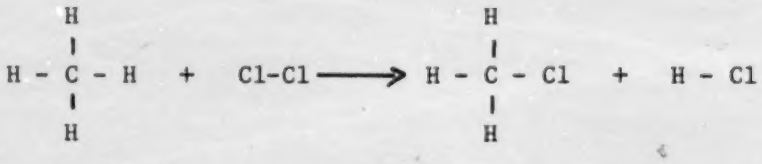
a) Mark her answer correct or incorrect.
b) Supply the correct sign.
c) If the answer is not correct, find how the student arrived at her answer. Explain the mistake she made.
d) Show all the work which the student failed to show.

Self Instructional Package No. 2
Tape 2 - Answer Sheet

METHANE

Assignment No. 1 - Energy aspect of the halogenation reaction

Chlorination of methane:



a) Bond Energies 104 kcal/mole 58 kcal/mole 84 kcal/mole 103 kcal/mole

Bonds cleaved: C - H Bond and Cl - Cl Bond

Bonds formed: C - Cl Bond and H - Cl Bond

E Required: 162 kcal/mole

E Released: 187 kcal/mole

b) ΔH for the chlorination reaction is: 162 - 187 = -25 kcal/mole

c) Chlorination of methane is an exothermic reaction

d) ΔH = -25 kcal/mole

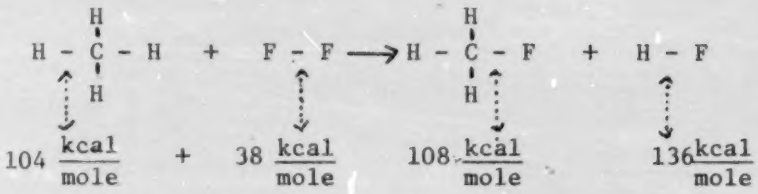
$$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl + 25 \text{ kcal/mole}$$

SIP No. 2
Tape 2 - Answer Sheet

Assignment No. 2

Fluorination of methane: $\Delta H = 102$

a) Reactions:



$$\Delta H = (104 + 38) - (108 + 136) = 142 - 244 = -102 \frac{kcal}{mole}$$

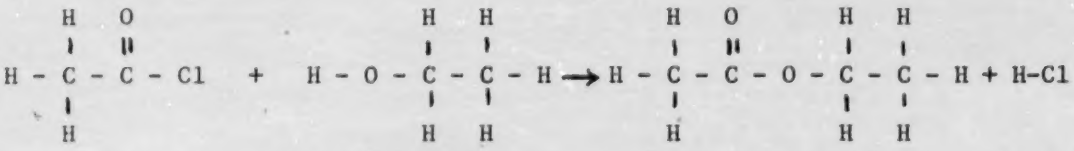
$$\Delta H = -102 \frac{kcal}{mole}$$

The missing factors are: 1. Sign indicating that the reaction is exothermic

2. Unit

Assignment No. 3

Esterification reaction:



Bond Energies: $74 \frac{kcal}{mole}$ $104 \frac{kcal}{mole}$ $36 \frac{kcal}{mole}$ $103 \frac{kcal}{mole}$

a) $\Delta H = (74 + 104) - (36 + 103) = 178 - 139 = +39 \frac{kcal}{mole}$

b) Esterification reaction above is an endothermic reaction

c) It will NOT take place spontaneously

SIP No. 2
Tape 2 - Answer Sheet

Assignment No. 4

Monobromination of methane:

Chain initiating step

Step 1. $Br \overset{\cdot}{\underset{\cdot}{|}} Br \longrightarrow 2\ Br^{\bullet} \qquad \Delta H = +46\ \frac{kcal}{mole}$

Chain propagating steps:

Step 2.
$$H - \underset{H}{\overset{H}{\overset{|}{\underset{|}{C}}}} - H + Br^{\bullet} \longrightarrow CH_3^{\bullet} + H - Br$$
$$104\ \frac{kcal}{mole} \qquad 88\ \frac{kcal}{mole}\ \ \Delta H_2 = 16\ \frac{kcal}{mole}$$

Endothermic

Step 3. $CH_3^{\bullet} + Br - Br \longrightarrow CH_3Br + Br^{\bullet}$

$46\ \frac{kcal}{mole} \qquad 70\ \frac{kcal}{mole}\ \ \Delta H_3 = 24\ \frac{kcal}{mole}$

Exothermic

Assignment No. 5

Monoiodination of methane:

Chain initiating step

Step 1. $I_2 \longrightarrow 2\ I^{\bullet} \qquad \Delta H_1 = 36\ \frac{kcal}{mole}$ (correct)

Chain propagating steps:

Step 2. $CH_4 + I^{\bullet} \longrightarrow CH_3^{\bullet} + HI \qquad \Delta H_2 = +33\ \frac{kcal}{mole}$ (correct)

$104\ \frac{kcal}{mole} \qquad 71\ \frac{kcal}{mole}$

Step 3. $CH_3^{\bullet} + I_2 \longrightarrow CH_3I + I^{\bullet}$

$36\ \frac{kcal}{mole} \quad 56\ \frac{kcal}{mole} \qquad \Delta H = -20\ \frac{kcal}{mole}$ (correct)

SIP No. 2
Tape 2 - Answer Sheet

Assignment No. 5 (continued)

Chain terminating steps:

$I^{\bullet} + T^{\bullet} \longrightarrow I_2 \qquad \Delta H_4 = -36 \frac{kcal}{mole}$

$CH_3^{\bullet} + I^{\bullet} \longrightarrow CH_3I \qquad \Delta H_5 = -56 \frac{kcal}{mole}$

$CH_3^{\bullet} + CH_3^{\bullet} \longrightarrow CH_3 - CH_3 \qquad \Delta H_6 = -88 \frac{kcal}{mole}$

ΔH, corresponds to Step 5. It should be properly written with a (+) or a (-) sign (-).

ΔH_2 corresponds to Step 1. It should be properly written with a (+) or a (-) sign (+).

ΔH_3 corresponds to Step 3. It should be properly written with a (+) or a (-) sign (-).

ΔH_4 corresponds to Step 2. It should be properly written with a (+) or a (-) sign. (+).

Assignment No. 6

Monobromination of methane:

From Assignment 4: ΔH_2 (Step 2) = + 16 $\frac{kcal}{mole}$

ΔH_3 (Step 3) = - 24 $\frac{kcal}{mole}$

ΔH (overall) = $\Delta H_2 + \Delta H_3 = + 16 - 24 = -8 \frac{kcal}{mole}$

Monoiodination of methane:

From Assignment 5: ΔH_2 (Step 2) = + 33 $\frac{kcal}{mole}$

ΔH_3 (Step 3) = -20 $\frac{kcal}{mole}$

ΔH (overall) = $\Delta H_2 + \Delta H_3 = + 33 - 20 = + 13 \frac{kcal}{mole}$

SIP No. 2
Tape 2 - Answer Sheet

Monofluorination of methane:

Answer submitted by Forgetful Flora:

$\Delta H = 64 \frac{kcal}{mole}$

a) Incorrect

b) Forgetful Flora has combined the ΔH's of not only the two chain propagating steps as she was supposed to do, but she combined the chain initiating step or Step 1 and the two chain propagating steps or Steps 2 and 3. She has also forgotten the sign which should have been (-).

Step 1

$F_2 \longrightarrow 2\ F^\circ \quad \Delta H_1 = +\ 38 \frac{kcal}{mole}$ (correct)

Step 2

$$CH_4 + F^\bullet \longrightarrow CH_3^\bullet + HF$$

$\Delta H_2 = -\ 32 \frac{kcal}{mole}$ (correct)

$104 \frac{kcal}{mole}$ $\qquad$ $136 \frac{kcal}{mole}$

Step 3

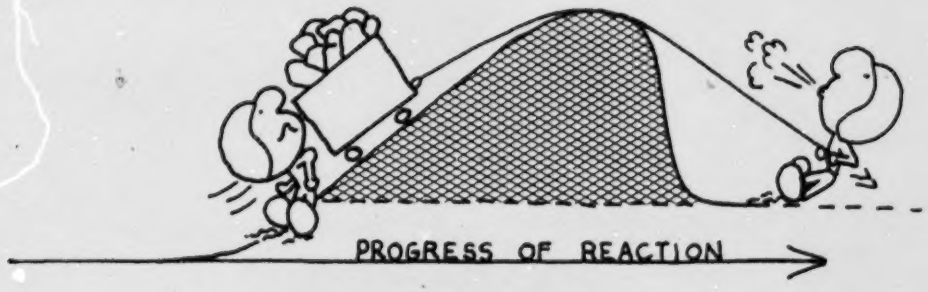
$$CH_3^\bullet + F_2 \longrightarrow CH_3F + F^\bullet$$

$\Delta H_3 = -70 \frac{kcal}{mole}$ (correct)

$38 \frac{kcal}{mole}$ $\qquad$ $108 \frac{kcal}{mole}$

$\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3 = +\ 38 - 32 - 70 = -64 \frac{kcal}{mole}$ (incorrect)

$\Delta H = \Delta H_2 + \Delta H_3 = -32 - 70 = -102 \frac{kcal}{mole}$ (correct)

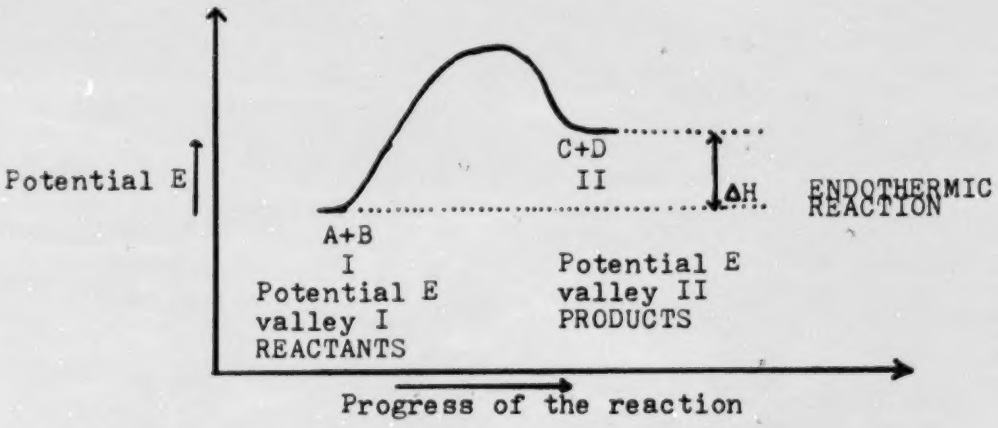


Self Instructional Package 2
Tape 3 - Worksheet

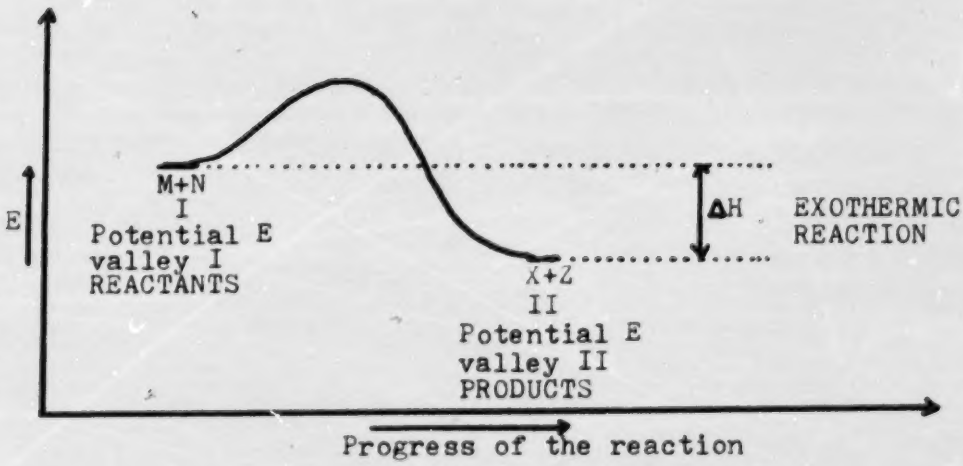
OBJECTIVES:

1. To learn how to draw an energy versus progress of reaction diagram (E diagram) for a given halogenation reaction.
2. To learn how to interpret a given E diagram.
3. To learn the meaning and the definition for the ACTIVATION ENERGY - E_{act}
4. To learn the meaning and the definition for the TRANSITION STATE.

Example 1. $A + B \longrightarrow C + D$



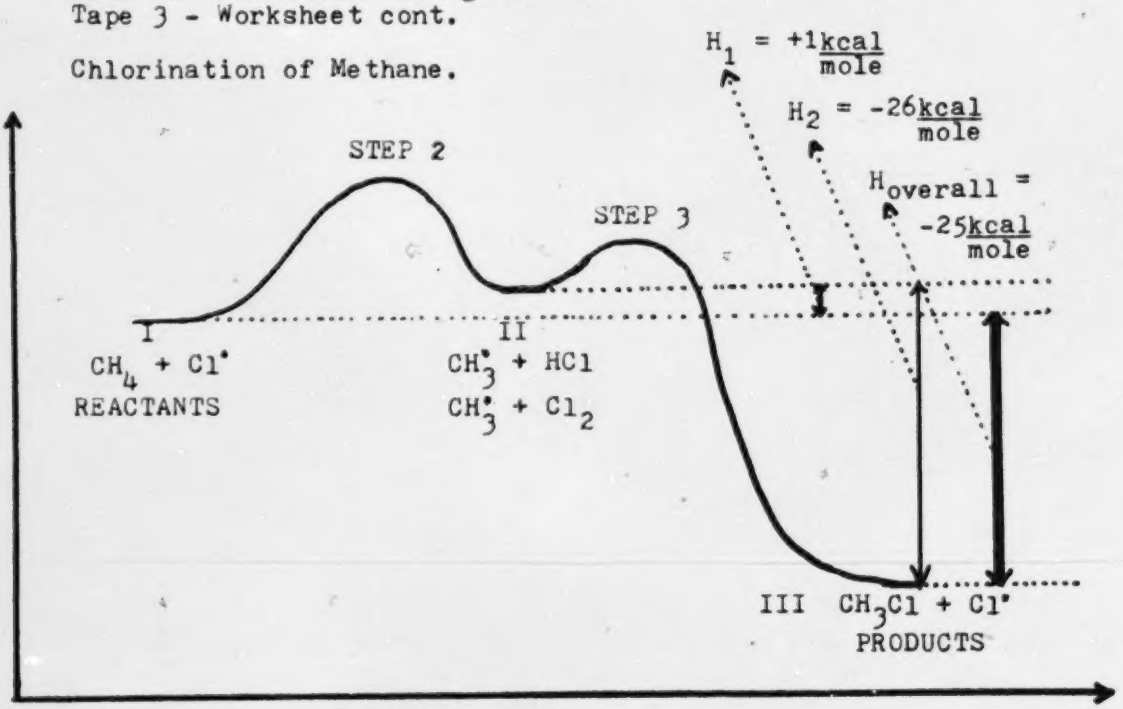
Example 2.



ASSIGNMENT 1. Draw the potential E versus progress of reaction diagram for the rate determining step for: a) the chlorination and b) the bromination reaction.

ASSIGNMENT 2. Draw the potential energy versus progress of reaction diagram for step 3 (formation of methyl chloride) for the chlorination reaction.

Example 3. Chlorination of Methane.



$\Delta H_{overall} = \Delta H_1 + \Delta H_2 = +1$ kcal/mole $- 26$ kcal/mole

$\Delta H_{overall} = -25$ kcal/mole.

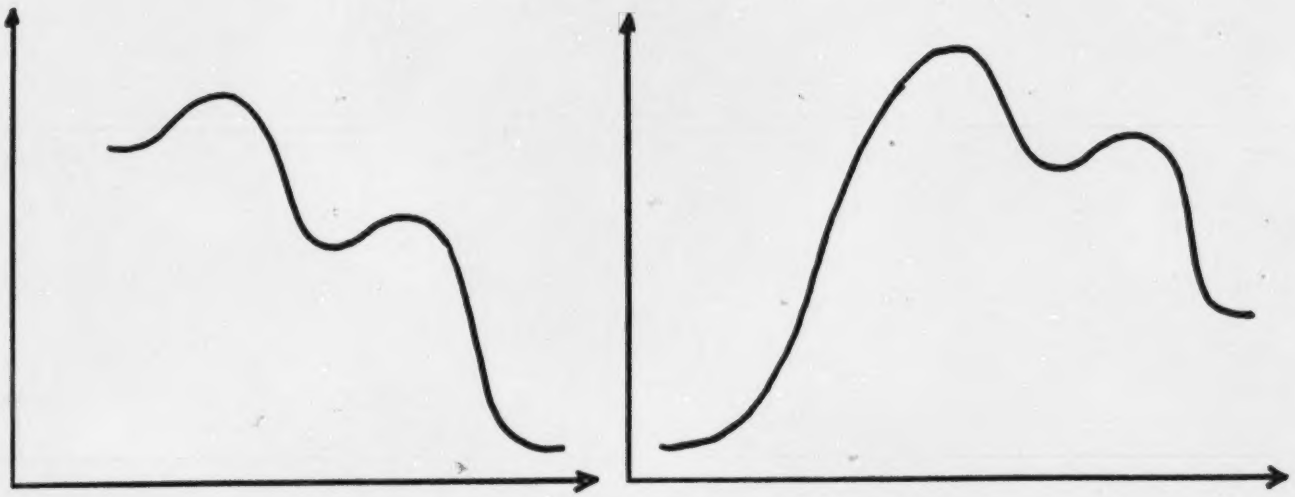
ASSIGNMENT 3.

a) Draw the potential E versus reaction progress diagram for the bromination of methane.
b) Indicate all particles involved i.e. reactants, products, and intermediate species.
c) Identify ΔH_1 , ΔH_2 , and the overall ΔH.

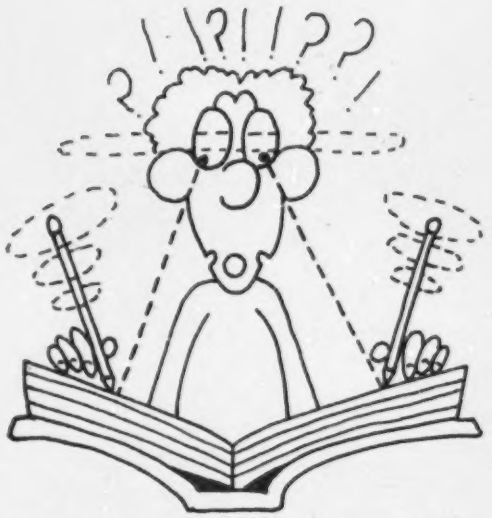
ASSIGNMENT 4.

Forgetful Frieda has been asked to draw energy diagrams for the iodination and fluorination reaction. Absent-mindedly she failed to label anything on either diagram. Your task is:

a) to identify the given diagram as the diagram for the fluorination or the iodination reaction.
b) to indicate all the particles involved and label them correctly on the diagram.
c) to assign the correct values for the ΔH's or heats of reaction for EACH STEP OF BOTH REACTIONS, and to clearly identify and label them on the diagram.
d) to assign the correct values for the ΔH's for the overall reactions and to identify them on the diagram.

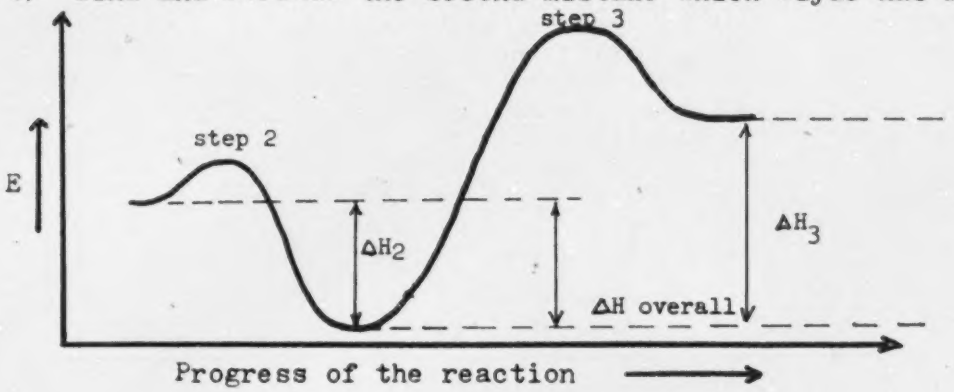


ASSIGNMENT 5.



Confused Clyde was asked to correctly draw the potential energy versus progress of reaction diagram for the mono-bromination reaction. He has dilligently and meticulously completed his assignment. However, being confused, as usual, he has made TWO mistakes. One is that he failed to indicate the particles and energies involved and to write them in their proper places on the diagram. It is your task now to:

a) complete Clyde's diagram with all the necessary notations and missing particles.
b) find and EXPLAIN the second mistake which Clyde has made.



ΔH_2 = -16 kcal/mole

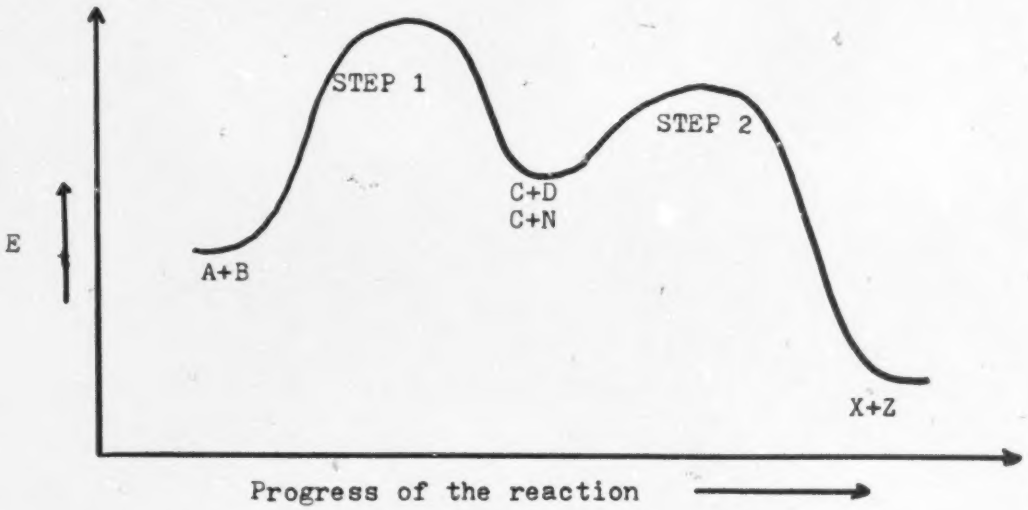
ΔH_3 = +24 kcal/mole

$\Delta H_{overall}$ = +8 kcal/mole

ASSIGNMENT 6. On the energy diagram from example three, identify and point out the E_{act} - activation energy - for the reaction:

$$CH_4 + Cl^{\bullet} \longrightarrow CH_3^{\bullet} + HCl$$

ASSIGNMENT 7. On the energy diagram below, identify:
a) the activation energies for step 1 and step 2.
b) ΔH_1 and ΔH_2.
c) overall ΔH.

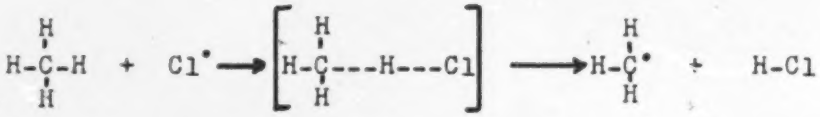


ASSIGNMENT 8. Label and assign the correct E_{act} for each step in the diagrams from the first five assignments.

Example 4.

$$CH_4 + Cl^{\bullet} \longrightarrow \left[H_3C\text{---}H\text{---}Cl\right] \longrightarrow H_3C^{\bullet} + HCl$$

REACTANTS TRANSITION STATE PRODUCTS



ASSIGNMENT 9. a) Draw the transition states for the chain initiating and the chain propagating steps for the monobromination reaction.
b) Identify the transition states for the two chain propagating steps on the diagram from assignment three.

Self Instructional Package No. 2
Tape 3 - Answer Sheet

METHANE

ENERGY DIAGRAM OF THE HALOGENATION REACTION

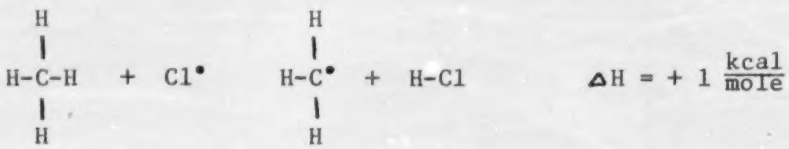
Assignment No. 1

Monochlorination reaction

The rate determining step or "The Difficult Step" in the mechanism is:

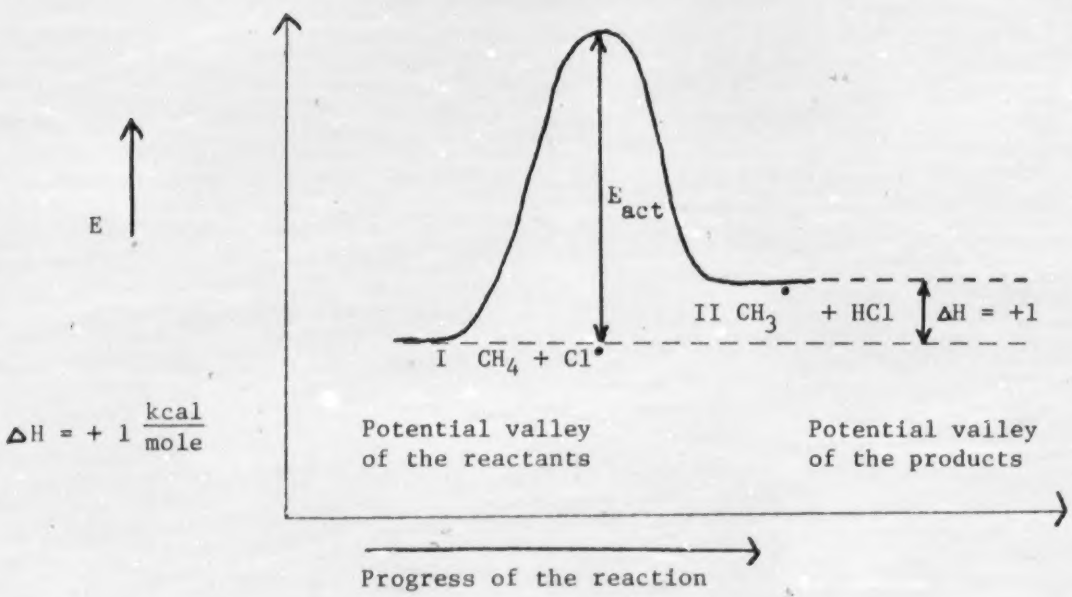
Step . (abstraction of H atom by the chlorine atom and the formation of methyl free radical)

Step 2.



$\Delta H = +1 \frac{kcal}{mole}$

104 kcal/mole 103 kcal/mole



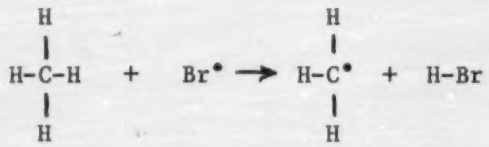
SIP No. 2
Tape 3 - Answer Sheet

Assignment No. 1 (continued)

Monobromination reaction

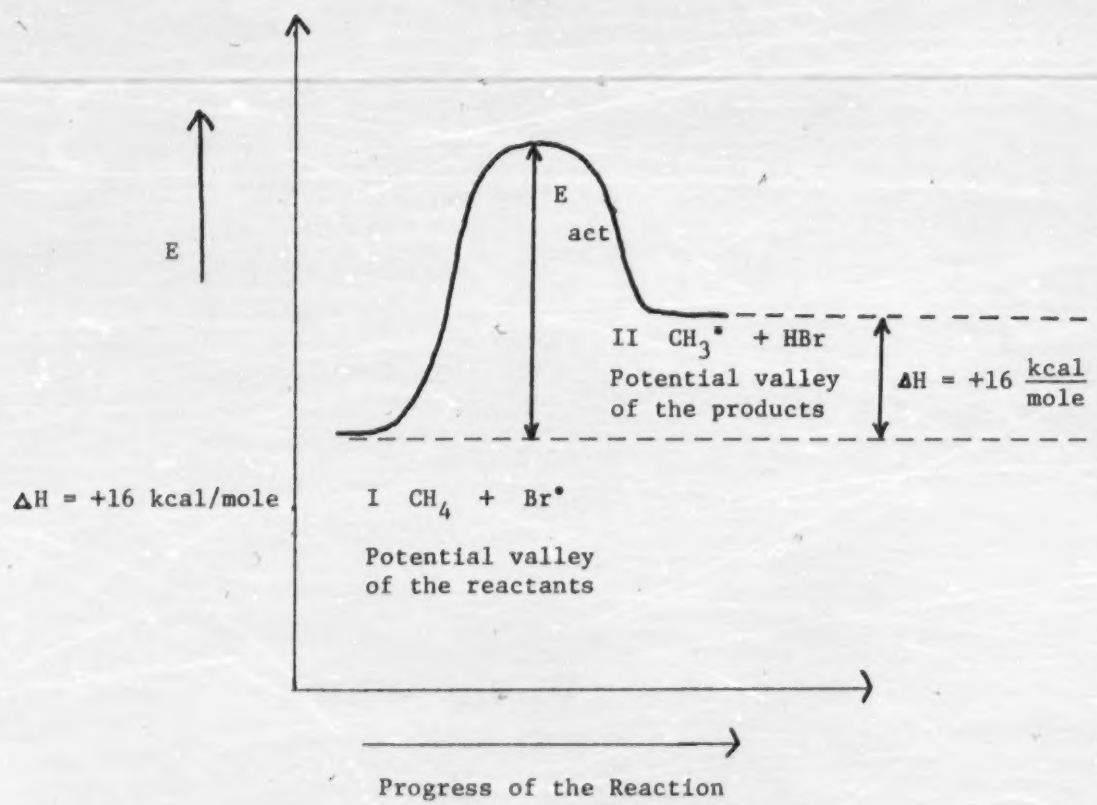
The rate determining step is the Step 2 (abstraction of H atom by the bromine atom and the formation of of methyl free radical.

Step 2.



$\Delta H = +16$ kcal/mole

104 kcal/mole 88 kcal/mole



SIP No. 2
Tape 3 - Answer Sheet

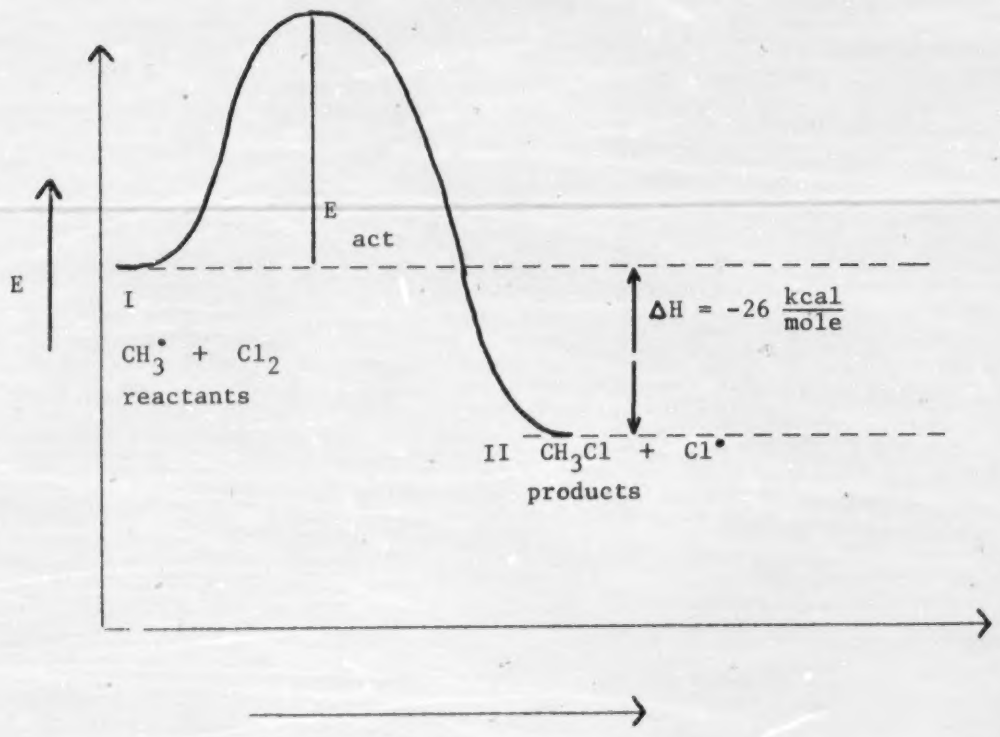
Assignment No. 2

Monochlorination reaction:

Step 3:

$$CH_3^{\bullet} + Cl_2 \longrightarrow CH_3Cl + Cl^{\bullet} \qquad \Delta H = -26 \frac{kcal}{mole}$$

$58 \frac{kcal}{mole}$ $\qquad$ $84 \frac{kcal}{mole}$



43

SIP No. 2
Tape 3 - Answer Sheet

Assignment No. 3

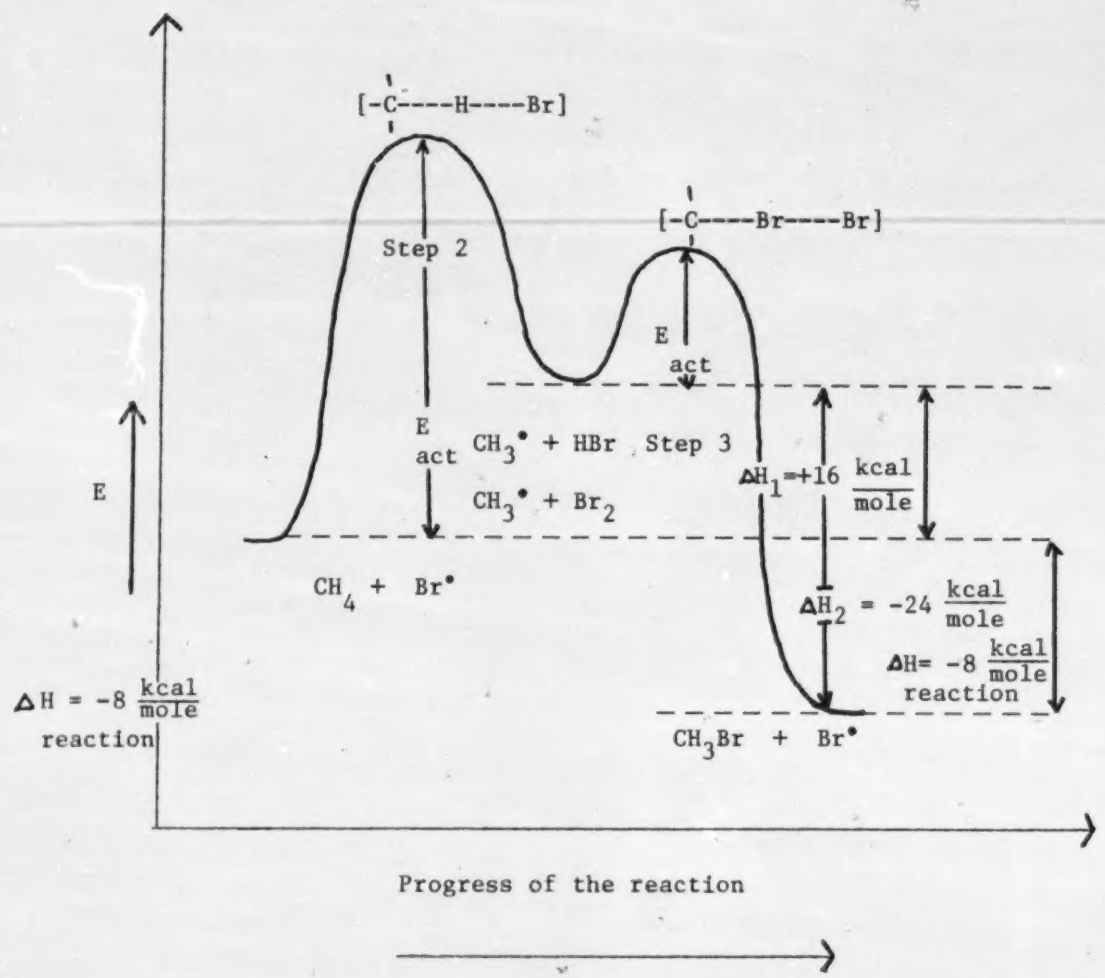
Potential E diagram for the bromination of methane

Step 2

$$CH_4 + Br^\bullet \longrightarrow CH_3^\bullet + HBr \qquad \Delta H_1 = +16 \frac{kcal}{mole}$$

Step 3

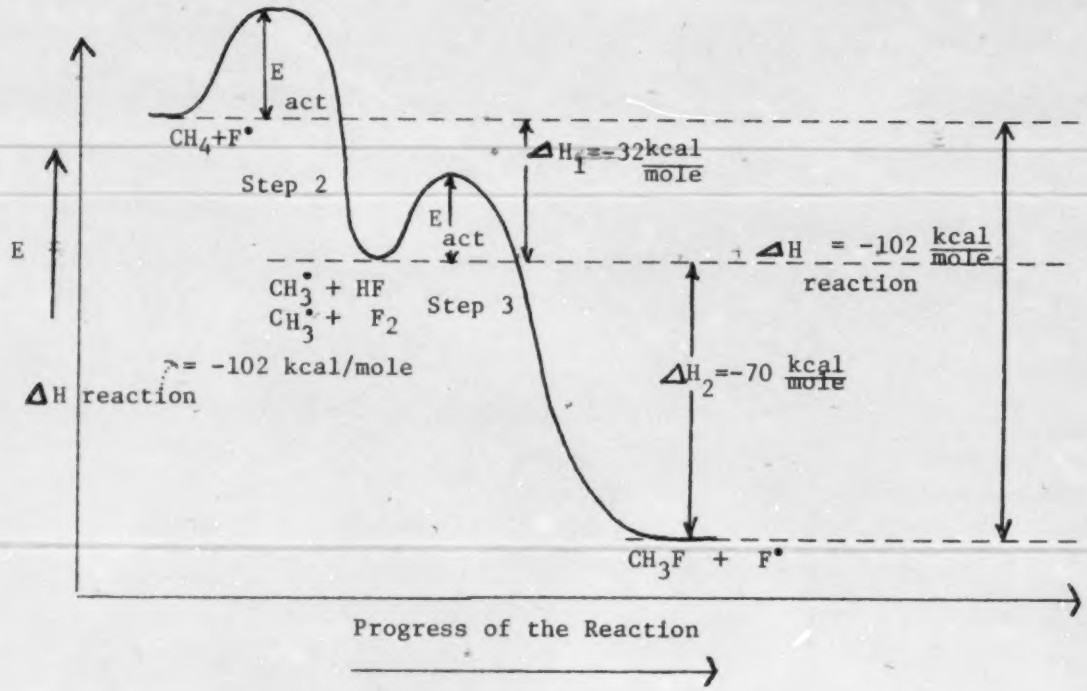
$$CH_3^\bullet + Br_2 \longrightarrow CH_3Br + Br^\bullet \qquad \Delta H_2 = -24 \frac{kcal}{mole}$$



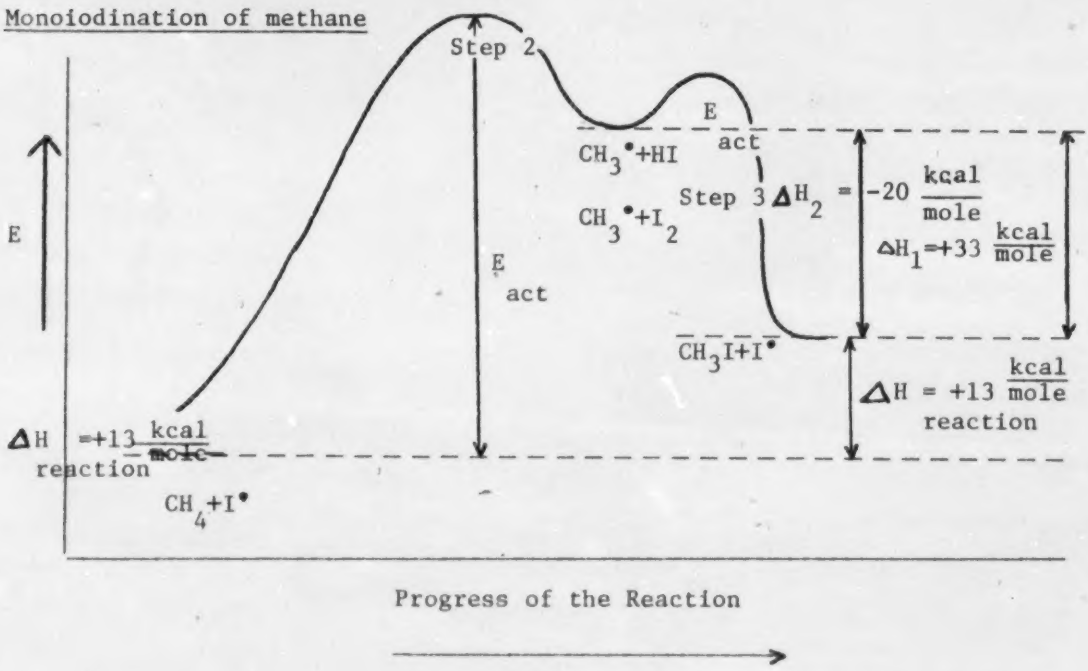
SIP No. 2
Tape 3 - Answer Sheet

Assignment 4

Monofluorination of methane



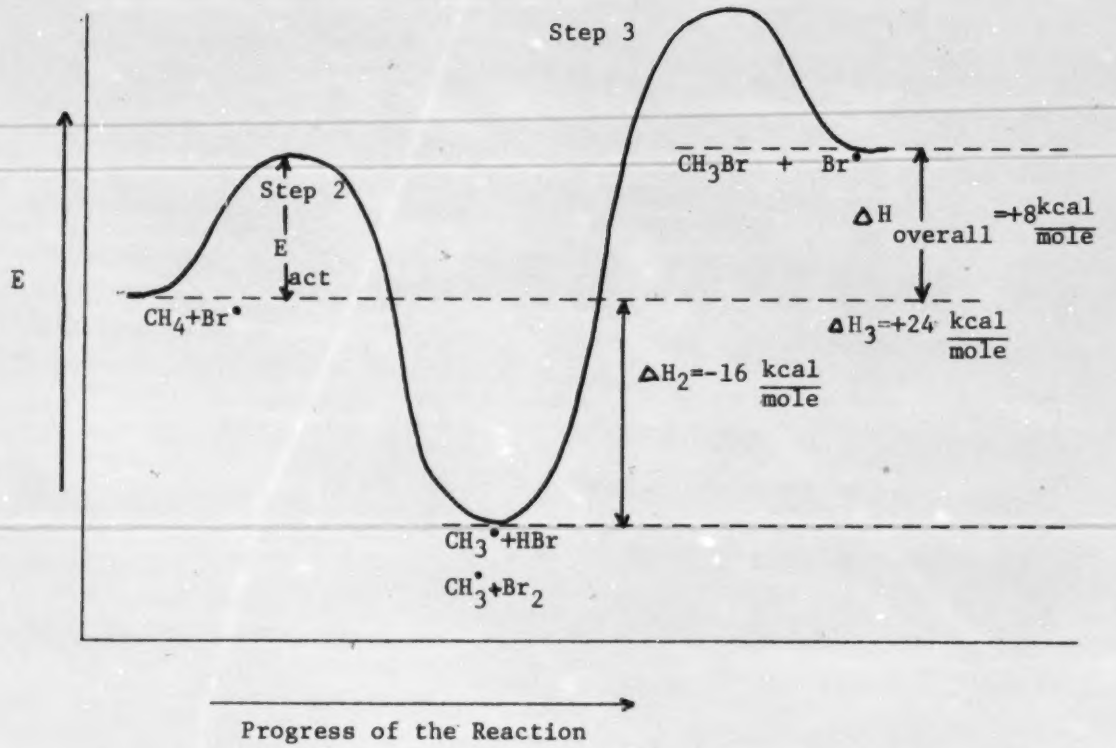
Monoiodination of methane



SIP No. 2
Tape 3 - Answer Sheet

Assignment No. 5

monobromination of methane

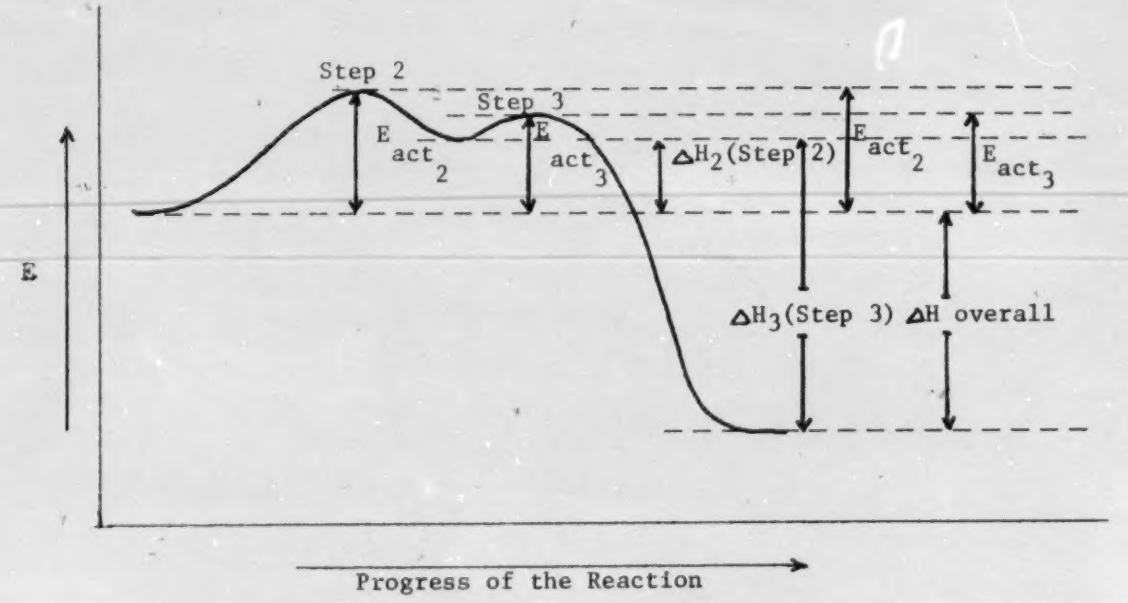


The diagram above is incorrect. The values assigned to ΔH, (Step 1) and (Step 2) have the opposite signs, consequently ΔH overall is incorrect. Compare this diagram to the correct diagram given the answer to Assignment No. 3.

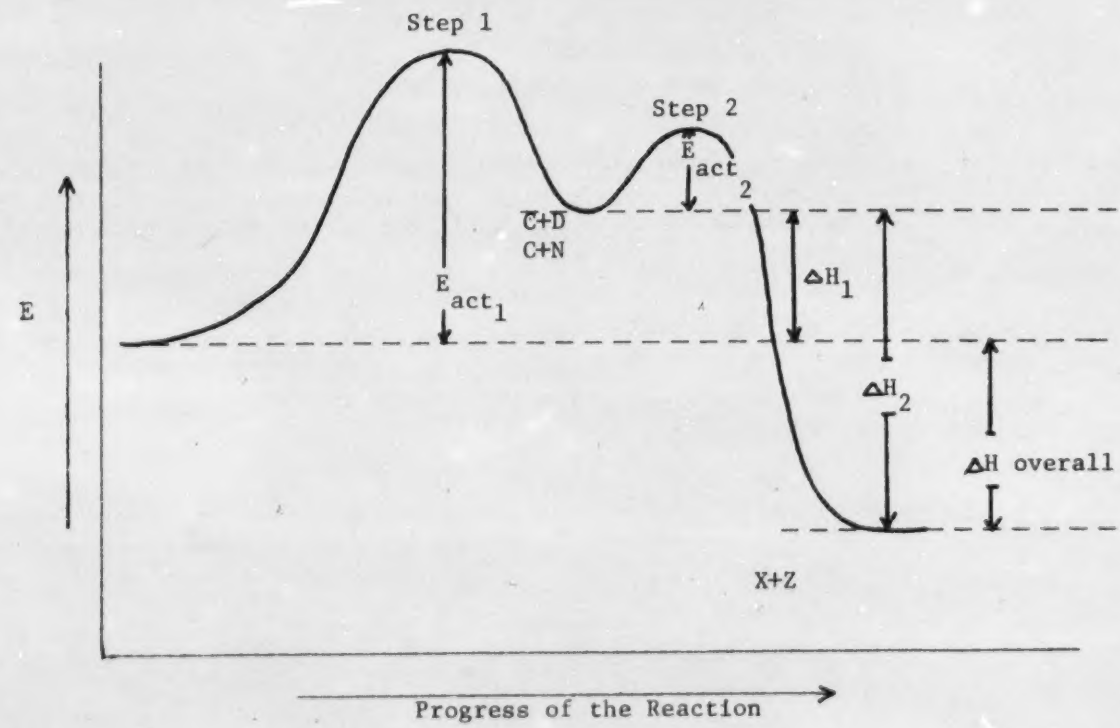
ΔH_2	$= -16\ \frac{kcal}{mole}$	(incorrect)	$\Delta H_2 = +16\ \frac{kcal}{mole}$	correct
ΔH_3	$= +24\ \frac{kcal}{mole}$	(incorrect)	$\Delta H_2 = -24\ \frac{kcal}{mole}$	correct
ΔH overall	$= +8\ \frac{kcal}{mole}$	(incorrect)	$\Delta H_{overall} = -8\ \frac{kcal}{mole}$	correct

SIP No. 2
Tape 3 - Answer Sheet

Assignment No. 6



Assignment No. 7



SIP No. 2
Tape 3 - Answer Sheet

Assignment No. 8

All the activation energies are indicated on each diagram.

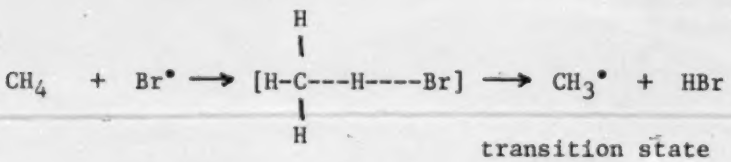
Assignment No. 9

a) monobromination of methane

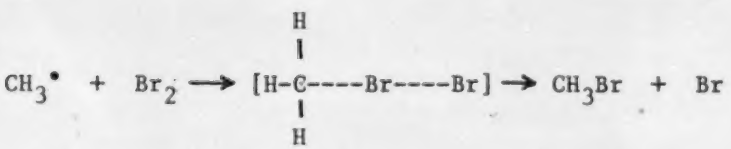
chain initiating step: $Br_2 \xrightarrow{E} [Br\text{-----}Br] \longrightarrow Br^{\bullet}$

transition state

chain propagating steps:



transition state



transition state

b) Refer back to the Assignment 3 - the transition states are identified in the diagram.

Self Instructional Package No. 2
Form D - Progress Check Evaluation

METHANE

You will fill out this exercise by blacking in the appropriate squares on an answer sheet. There may be more than one correct answer for each question.

1. Correct statements pertaining to methane are:

   a) The angles in methane are 109°.

   b) C in methane has sp^3 hybrid orbitals, consequently methane is pyramidal.

   c) C in methane has sp^2 hybrid orbitals, consequently methane is tetrahedral.

   d) The hybridization on the C atom in methane is sp^3.

2. Methane is a gas at room temperature due to:

   a) the weak intermolecular forces between methane molecules.

   b) the fairly strong Van der Waals forces between methane molecules.

   c) the tetrahedral shape of methane.

   d) the fact that methane is a nonpolar molecule.

3. Correct statements pertaining to methyl free radical are:

   a) C atom in the methyl free radical has sp^2 hybridization, consequently methyl free radical is flat trigonal.

   b) The angles in the methyl free radical are 120° because of the sp^3 hybridization on the C atom.

   c) The angles in the methyl free radical are 109°.

   d) The unpaired electron in the methyl free radical is located in the p atomic orbital.

4. From the compounds given below identify the trihalomethane.

   a) CH_2I_2

   b) $CHBr_3$

   c) CH_3Cl

   d) CF_4

5. A typical substitution reaction of methane is a reaction:

   a) which results in the formation of monohalomethane.

   b) in which a hydrogen atom is substituted by any other atom.

   c) in which methane is converted into carbon dioxide and water.

   d) which is highly exothermic.

6. In order to minimize the formation of the di, tri and tetrasubstituted halogen derivatives of methane and obtain the highest percent of the monohalo derivative, the following should be done:

   a) Low concentration of halogen should be used.

   b) Excessive amount of methane should be used.

   c) Monohalomethane should be removed from the mixture.

   d) Limited amount of energy should be applied.

7. The correct statements about the rate of reaction are:

   a) It is independent of the concentration of the reactants.

   b) It is independent of the concentration of the products.

   c) It is directly proportional to the concentration of the reactants.

   d) It is dependent on the heat of the reaction.

8. Which one of the following is/are free radicals?

   a) $Na^{\bullet}$ b) $:\ddot{S}:^{--}$ c) K^{+} d) $C_2H_5^{\bullet}$

9. Reaction of halogen atom with methyl free radical is:

   a) a chain terminating step

   b) a chain propagating step

   c) a chain initiating step

   d) the rate determining step

10. Chlorine atom reacts with methane to produce:

    a) Methyl chloride and hydrogen chloride

    b) Methyl chloride and chlorine atom

    c) Methyl free radical and chlorine atom

    d) Methyl free radical and hydrogen chloride

11. Methyl free radical reacts in the chain propagating step with:

    a) chlorine atom to produce methyl chloride.

    b) chlorine molecule to produce methyl chloride and hydrogen chloride.

    c) chlorine molecule to produce methyl chloride and chlorine atom.

    d) hydrogen chloride to produce methyl chloride and hydrogen atom.

12. The rate determining step in the monohalogenation of methane reaction is:

    a) dissociation of halogen molecule to produce halogen atoms.

    b) reaction of methyl free radical with halogen atom.

    c) reaction of methyl free radical with halogen molecule.

    d) reaction of methane with halogen atom.

13. In the rate determining step of the monohalogenation of methane reaction, the products are:

    a) two halogen atoms.

    b) halogen atom and methyl halide.

    c) hydrogen halide and methyl free radical.

    d) halogen atom and methyl free radical.

14. Dissociation of halogen molecule to produce two halogen atoms is:

    a) a chain terminating step

    b) a chain propagating step

    c) a chain initiating step

    d) the rate determining step

15. A reaction of methane with halogen atom is:

    a) a chain terminating step

    b) a chain propagating step

    c) a chain initiating step

    d) the rate determining step

16. A reaction of halogen atom with methane to produce methyl halide and hydrogen halide is:

    a) a chain terminating step

    b) a chain propagating step

    c) incorrect

    d) the rate determining step

17. The function of the heat or light in the halogenation of methane reaction is:

    a) to initiate the reaction

    b) to catalyze the reaction

    c) to inhibit the reaction

    d) to keep the reaction going

18. Oxygen if present in the halogenation of methane will:

    a) speed up the reaction

    b) slow down the reaction

    c) catalyze the reaction

    d) inhibit the reaction

19. The activation energy can be defined or described as:

    a) the difference in the energy content of reactants and the products.

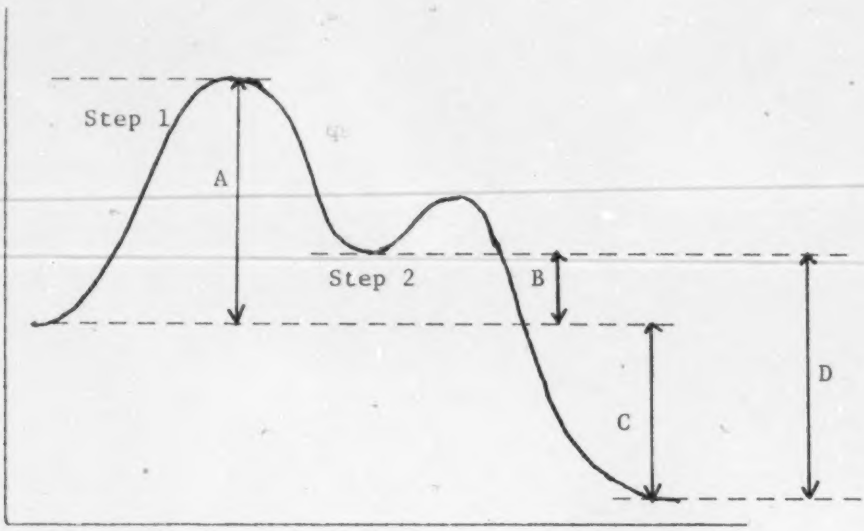
    b) the difference in the energy content of reactants and the transition state.

    c) the minimum amount of energy required for a productive collision.

    d) the energy required for the reaction to take place.

SIP No. 2
Form D - Progress Check Evaluation

The following four questions refer to the diagram below:



20. The energy difference A on the diagram is the:

    a) ΔH or heat of the overall reaction.

    b) activation energy of the first step.

    c) activation energy of the overall reaction.

    d) ΔH or heat of the first step.

21. The heat of the overall reaction depicted by the diagram above is the energy difference:

    a) A

    b) B

    c) C

    d) D

22. The correct statements about the reaction depicted by the diagram above are:

    a) The rate determining step in this reaction is Step 1.

    b) The overall reaction is an endothermic reaction.

    c) ΔH for the overall reaction will have a negative sign.

    d) Step 2 of the mechanism is exothermic.

23. The energy difference D is:

    a) the difference in the energy content of the reactants and the products.

    b) the ΔH or the heat for Step 1.

    c) the ΔH or the heat for Step 2.

    d) the value which may be obtained by subtracting B from C.

Use the bond energy card in order to correctly answer the following three questions.

24. ΔH or heat for the rate determining step of the monobromination of methane reaction is:

    a) +46 kcal/mole

    b) +16 kcal/mole

    c) -24 kcal/mole

    d) -8 kcal/mole

25. ΔH or heat for the iodination reaction is:

    a) +36 kcal/mole

    b) +13 kcal/mole

    c) $\Delta H_1 + \Delta H_2 + \Delta H_3$ or $+36 + 33 - 20$

    d) $\Delta H_2 + \Delta H_3$ or $+33 - 20$

26. -108 kcal/mole in the monofluorination reaction is the ΔH or heat for the following step of the mechanism.

a) $F_2 \xrightarrow{\Delta \text{ or } h\nu} 2F^{\bullet}$

b) $CH_4 + F^{\bullet} \longrightarrow CH_3^{\bullet} + HF$

c) $CH_3^{\bullet} + F_2 \longrightarrow CH_3F + F^{\bullet}$

d) $CH_3^{\bullet} + F^{\bullet} \longrightarrow CH_3F$

27. From the values for the activation energy for the rate determining step of the monohalogenation reaction, which are: F_2 + 1 kcal/mole Cl_2 + 4 kcal/mole; Br_2 + 18 kcal/mole; I_2 + 35 kcal/mole; the reactivity of these halogens is expected to be:

a) $F_2 > Br_2 > Cl_2 > I_2$

b) $I_2 > Br_2 > Cl_2 > F_2$

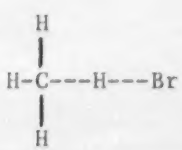
c) $F_2 > Cl_2 > Br_2 > I_2$

d) $Cl_2 > Br_2 > F_2 > I_2$

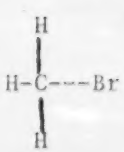
28. Transition state for the rate determining step of the monobromination reaction can be written as:

a) Br-----Br

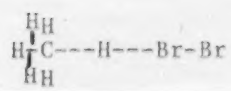
b)



c)



d)



Self Instructional Package No. 2
Form B[1] - Self Evaluation Exercise - Answer Sheet

METHANE

1. d
2. d
3. d
4. b
5. b
6. c
7. b, d
8. c, d
9. a, c, d
10. a, b, d
11. a
12. d
13. a, c, d
14. a, b
15. b
16. b
17. b
18. b, d
19. d
20. b
21. b, d
22. c
23. a

Self Instructional Package No. 2
Form D' - Progress Check Evaluation - Answer Sheet

METHANE

1.	a, d	15.	b, d
2.	a	16.	c
3.	a, d	17.	a
4.	b	18.	b, d
5.	b	19.	b, c
6.	a, b, c	20.	b
7.	b, c	21.	c
8.	a, d	22.	a, c, d
9.	a	23.	c
10.	d	24.	b
11.	c	25.	b, d
12.	d	26.	d
13.	c	27.	a
14.	c	28.	d

CHEM 201

S.I.P #2 - ERRATA

CORRECT STATEMENTS AND ANSWERS

FORM B - 18 d — In an endothermic reaction products possess a higher amount of potential energy or "they have a potential energy valley" than the reactants.

FORM B[1] - Answer Sheet

1. d, b
5. a, b
22. b

FORM D[1] - Answer Sheet

5. a, b
27. c
28. b

TAPE 3 - Answer Sheet

Assignment #4. Monoidonitation of methane: ΔH_1 is missing on the diagram.
ΔH_1 = +33 kcal/mole -- the line should be drawn from the first valley of the products to the reactants at the beginning of the reaction. (it should connect the two dotted lines.)